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Comparison of Abdominal Visceral Adipose Tissue Measurements in Adolescents between Magnetic Resonance Imaging and Dual-energy X-ray Absorptiometry

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Abstract

Excess abdominal visceral adipose tissue (VAT) is associated with cardiometabolic risk factors in adolescents. VAT is mainly measured using Magnetic Resonance Imaging (MRI), yet dual-energy x-ray absorptiometry (DXA) is more affordable and available. The purpose was to compare adolescent VAT values obtained by MRI and DXA. A sample of 330 adolescents 10–16 years of age were recruited (52.3% female, 58.5% White). Abdominal VAT was measured using a General Electric (GE) Signal MRI Excite scanner with imaging software. A whole-body DXA (GE iDXA) scan was performed, and software calculated VAT within the android region. Wilcoxon signed-rank t-tests were used to determine differences between VAT values, within sex, race (White, African American, and Other race), and BMI categories (normal weight, overweight, and obese). VAT values from MRI and DXA were significantly correlated (r=0.78, p<0.001). Average VAT from MRI (0.54±0.43 kg) was significantly higher than VAT from DXA (0.33±0.39 kg) in the overall sample (p<0.001) and within all subgroups (p<0.001). All standardized values between the two measurements fell within ±1.96 standard deviations, and differences between the methods were not associated with level of VAT. In this sample, DXA values were correlated with MRI values, but DXA consistently underestimated VAT compared to MRI.

Keywords

child; visceral fat; imaging

Introduction

Adolescents with obesity are five times more likely to have adult obesity(1). Yet, adipose distribution differs by subgroups, including sex, race, and body fat percentage(2). High visceral adipose tissue (VAT), a metabolically active adipose tissue found in the abdominal

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cavity, is associated with increased risk for all-cause and cancer-specific mortality(3, 4). Excess VAT in adolescence is associated with early health risks, including insulin resistance and fatty liver(5, 6).

The two standards for measuring VAT are magnetic resonance imaging (MRI) and computed tomography, which are both costly, widely inaccessible, and time-intensive techniques. Dual energy X-ray absorptiometry (DXA) is a more economical and available tool that can also identify VAT. A recent study using the General Electric (GE) DXA reported high correlations with MRI measured VAT in adolescent females (9–13 years of age, *rho*=0.76, DXA: 0.23±0.22kg, MRI: 0.06±0.03kg)(7). It is unclear if these techniques are correlated when considering other subgroups as research suggests less agreement in higher body mass index (BMI) categories(8). Therefore, the purpose of this study was to compare VAT values between MRI and DXA using a diverse adolescent cohort.

Methods

Adolescents ages 10–16 years were recruited to participate in a prospective observational cohort study between August 2016 and August 2018 in a metropolitan area of the southeastern United States. This cross-sectional analysis utilized baseline measurements only, as follow-up measurements are ongoing. Parents of adolescents were recruited using convenience sampling. Exclusion criteria included a body weight ≥500 pounds, pregnancy, medically restrictive diet, and significant mental or physical disabilities that hindered mobility. Pennington Biomedical Research Center’s Institutional Review Board approved this study (IRB #2016–028).

Parents or guardians provided written consent and the adolescent provided written assent. Adolescents arrived after an overnight fast to complete imaging (MRI and DXA) and anthropometry on the same day. A trained research assistant measured height and weight twice to the nearest 0.1 cm or 0.1 kg, respectively. Age- and sex-specific BMI percentiles were calculated based on national reference data(9). Adolescents were grouped into BMI categories, including normal weight (<85th percentile), overweight (≥85th to <95th percentile), and obesity (≥95th percentile)(9). Parents reported the adolescent’s age, sex, and race on a questionnaire. Questionnaires were managed using the Research Electronic Data Capture (REDCAP) tool, hosted at Pennington Biomedical Research Center(10).

Dual energy X-ray Absorptiometry

A trained technician performed a whole-body scan with a General Electric (GE) Lunar iDXA scanner (GE Medical Systems, Milwaukee, WI) using a standard positioning protocol. VAT mass was estimated using the enCORE software with CoreScan (version 13.60.033, GE Healthcare). CoreScan identified total fat in the android region, defined as the lower 20% of the area between the iliac crest and the base of the skull. A validated algorithm calculated VAT mass using estimates of total fat and subcutaneous fat(11). Adolescents who exceeded the scan region (*n*=21) were positioned with their left arm excluded, and their right arm measurements were duplicated for analysis.

Magnetic Resonance Imaging

A water-fat shifting MRI was also used to assess VAT, with a GE Discovery 750w 3.0 Tesla (GE Medical Systems, Milwaukee, WI). Images were captured using IDEAL-IQ imaging software during a single acquisition with a 20-second breath-hold. Images from the highest point of the liver to the bottom of the right kidney were acquired. A trained technician assessed images with Analyze software (CNSoftware, Rochester, MN) and manually drew VAT area using each 5th slice, beginning two slices before the L4/5 until the diaphragm (~5–6 images total). In a previous study, this trained technician demonstrated a high correlation between repeated measures (0.97) when reanalyzing a random subset of images(12). Similar to another study(13), the identified VAT (pixels) in each image was multiplied by voxel width (mm) and height (mm); then by 0.000001 and 5 (between slice number) and voxel depth (9.9 or 10mm depending on image). This calculated volume was multiplied by 0.9193 to estimate mass (kg).

Statistical Analysis

VAT values were non-normally distributed as assessed via a Shapiro-Wilk test (p=0.001). A Spearman-rank order correlation was used to estimate the correlation between DXA and MRI values. Wilcoxon rank sum tests were used to evaluate differences between values by sex, race (White, African American, or Other Race), and BMI category (normal, overweight, and obese). VAT values were standardized to a mean of zero and unit standard deviation and compared with a Bland Altman plot. Linear regression was used to assess the relationship between the mean ((MRI + DXA)/2) and difference (MRI – DXA) in VAT, using unstandardized and standardized values. Statistical significance was set at $p<0.05$. All analyses were performed using SAS 9.4 (Cary, N.C.).

Results

Overall, 342 adolescents participated and 330 provided complete data for analysis, with three adolescents missing both measurements and nine adolescents missing an MRI scan. On average, adolescents were 12.6±1.9 years of age, 52.3% were female, and 58.5% were White, 35.5% were African American, and 6.0% were Other Race. In total, 52.4% had normal weight, 14.6% had overweight, and 33.0% had obesity. The average DXA VAT value was 0.33±0.39kg and MRI VAT value was 0.54±0.43kg.

MRI and DXA values were highly correlated (rho=0.78, $p<0.001$), demonstrating a strong positive relationship. The absolute error (0.20±0.18kg) and error (−0.20±0.18kg) indicated DXA consistently measured lower than MRI. DXA values were significantly lower than MRI values in each subgroup ($p<0.001$ for all, Table 1). DXA values were closest to MRI values in African Americans (−0.12±0.19kg) and furthest away for adolescents with overweight (−0.28±0.16kg). There was no difference between standardized DXA and MRI values (p=0.81). Using a Bland-Altman plot, all standardized values fell within 1.96 standard deviations and clustered towards the mean standardized value of 0.0±0.5, suggesting good overall agreement (Figure 1). The unstandardized mean value was significantly associated with the difference in VAT values (β=0.10, SE=0.02, $p<0.001$), suggesting a greater difference as the mean increased. There was no trend across levels of standardized mean (p>0.05) suggesting that the errors did not change across levels when standardized.

Discussion

DXA and MRI values of VAT correlated well, yet values were not directly comparable. DXA values were consistently lower than MRI values in each subgroup, signifying a systematic difference between devices. These findings propose that DXA values may yield similar associations with outcomes as MRI values.

Another study in adolescent females found similar high correlations between DXA and a smaller MRI area (four intervertebral slices) but did not compare actual values between the devices(14). An investigation using an updated CoreScan (version 16) and MRI found DXA underestimated VAT in older men with an absolute bias of 30%, but had good agreement(15). Those authors posited that DXA underestimated because CoreScan measures a smaller area, as in the lower 20% (~10 cm), compared to abdominal MRI which measures between L4/L5 to the kidney (~16 cm). Regrettably, CoreScan does not provide exact region dimensions to use for replication with abdominal MRI. This underestimation may lead to an inaccurate health assessment, as a study in adults found that VAT quantity, as in an additional 500 cm^3 (or 0.45 kg), was associated with increased cardiovascular disease risk(16).This finding may be software specific, as comparisons of other DXA machines (i.e. Hologic) reported DXA overestimating VAT compared to MRI(8, 17).

Differences between values persisted across BMI categories. A study in adults observed that agreement between devices differs across BMI categories, with a larger difference in overweight and obese categories(8). Others hypothesize these differences are due to CoreScan’s ability to distinguish between subcutaneous fat and VAT in the abdominal region(18). Further, CoreScan’s estimation of VAT vary more in higher BMI categories, as another study in adults found a significant bias between two duplicate DXA measurements using an updated CoreScan (version 16) in overweight and obesity categories but not in the normal weight category(19).

The smallest difference in VAT measurements was in African American adolescents compared to other subgroups. Other studies report African Americans have lower abdominal VAT relative to Whites(2, 20). The degree to which this race difference in VAT contributes to the observations in the present study is not known. However, the current results suggests that DXA may provide a better estimation of VAT in African American adolescents compared to other races.

Strengths of the current study include the diverse sample and use of a 3.0 Tesla MRI with manual identification of VAT from a trained technician of high reliability. One limitation is that the current study does not have access to the CoreScan proprietary algorithm, which impedes algorithm-specific recommendations. Yet population level differences may provide insight to software developers and researchers on the systematic differences between techniques. Unfortunately, recent CoreScan software (versions greater than 13.60) do not output VAT values for subjects below 18 years of age, which has caused some researchers to override this stipulation by adjusting birthdates(14). Currently, an adolescent option is not available in the software. Future studies could examine CoreScan's variability in adolescents, and the influence of adolescent-specific factors (i.e. puberty)(5).

Overall, DXA underestimated VAT when compared to MRI values, though there is good agreement between techniques. These findings, along with other replications, may provide justification for the use of DXA to measure VAT in adolescents.

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List of Abbreviations:

BMI	Body Mass Index
DXA	Dual X-ray Absorptiometry
GE	General Electric
MN	Minnesota
MRI	Magnetic Resonance Imaging
VAT	Visceral Adipose Tissue
WI	Wisconsin

REFERENCES

1. Simmonds M, Llewellyn A, Owen CG, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. Obes Rev. 2016;17(2):95–107. [PubMed: 26696565]
2. Staiano AE, Broyles ST, Gupta AK, Katzmarzyk PT. Ethnic and sex differences in visceral, subcutaneous, and total body fat in children and adolescents. Obesity (Silver Spring). 2013;21(6):1251–5. [PubMed: 23670982]
3. Brown JC, Harhay MO, Harhay MN. Visceral adipose tissue dysfunction and mortality among a population-based sample of males and females. Diabetes Metab. 2016;42(5):382–5. [PubMed: 27283873]
4. Katzmarzyk PT, Mire E, Bouchard C. Abdominal obesity and mortality: The Pennington Center Longitudinal Study. Nutr Diabetes. 2012;2:e42. [PubMed: 23168527]

5. Caprio S, Perry R, Kursawe R. Adolescent Obesity and Insulin Resistance: Roles of Ectopic Fat Accumulation and Adipose Inflammation. Gastroenterology. 2017;152(7):1638–46. [PubMed: 28192105]
6. Umano GR, Shabanova V, Pierpont B, Mata M, Nouws J, Trico D, et al. A low visceral fat proportion, independent of total body fat mass, protects obese adolescent girls against fatty liver and glucose dysregulation: a longitudinal study. Int J Obes (Lond). 2019;43(4):673–82. [PubMed: 30337653]
7. Lee V, Blew R, Hetherington-Rauth M, Blew D, Galons JP, Hagio T, et al. Estimation of visceral fat in 9- to 13-year-old girls using dual-energy X-ray absorptiometry (DXA) and anthropometry. Obes Sci Pract. 2018;4(5):437–47. [PubMed: 30338114]
8. Neeland IJ, Grundy SM, Li X, Adams-Huet B, Vega GL. Comparison of visceral fat mass measurement by dual-X-ray absorptiometry and magnetic resonance imaging in a multiethnic cohort: the Dallas Heart Study. Nutr Diabetes. 2016;6(7):e221. [PubMed: 27428873]
9. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, et al. 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat 11. 2002(246):1–190.
10. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42(2):377–81. [PubMed: 18929686]
11. Kaul S, Rothney MP, Peters DM, Wacker WK, Davis CE, Shapiro MD, et al. Dual-energy X-ray absorptiometry for quantification of visceral fat. Obesity (Silver Spring). 2012;20(6):1313–8. [PubMed: 22282048]
12. Harrington DM, Staiano AE, Broyles ST, Gupta AK, Katzmarzyk PT. Waist circumference measurement site does not affect relationships with visceral adiposity and cardiometabolic risk factors in children. Pediatr Obes. 2013;8(3):199–206. [PubMed: 23172858]
13. Arif H, Racette SB, Villareal DT, Holloszy JO, Weiss EP. Comparison of methods for assessing abdominal adipose tissue from magnetic resonance images. Obesity (Silver Spring). 2007;15(9):2240–4. [PubMed: 17890492]
14. Lee V, Blew R, Hetherington-Rauth M, Blew D, Galons J-P, Hagio T, et al. Estimation of visceral fat in 9- to 13-year-old girls using dual-energy X-ray absorptiometry (DXA) and anthropometry. Obesity Science & Practice. 2018;4(5):437–47. [PubMed: 30338114]
15. Cheung AS, de Rooy C, Hoermann R, Gianatti EJ, Hamilton EJ, Roff G, et al. Correlation of visceral adipose tissue measured by Lunar Prodigy dual X-ray absorptiometry with MRI and CT in older men. Int J Obes (Lond). 2016;40(8):1325–8. [PubMed: 27003112]
16. Lee JJ, Pedley A, Hoffmann U, Massaro JM, Fox CS. Association of Changes in Abdominal Fat Quantity and Quality With Incident Cardiovascular Disease Risk Factors. J Am Coll Cardiol. 2016;68(14):1509–21. [PubMed: 27687192]
17. Dias KA, Ramos JS, Wallen MP, Davies PSW, Cain PA, Leong GM, et al. Accuracy of Longitudinal Assessment of Visceral Adipose Tissue by Dual-Energy X-Ray Absorptiometry in Children with Obesity. J Obes. 2019;2019:2193723. [PubMed: 31781386]
18. Ergun DL, Rothney MP, Oates MK, Xia Y, Wacker WK, Binkley NC. Visceral Adipose Tissue Quantification Using Lunar Prodigy. Journal of Clinical Densitometry. 2013;16(1):75–8. [PubMed: 23148876]
19. Meredith-Jones K, Haszard J, Stanger N, Taylor R. Precision of DXA-Derived Visceral Fat Measurements in a Large Sample of Adults of Varying Body Size. Obesity (Silver Spring). 2018;26(3):505–12. [PubMed: 29286209]
20. Katzmarzyk PT, Bray GA, Greenway FL, Johnson WD, Newton RL Jr., Ravussin E, et al. Racial differences in abdominal depot-specific adiposity in white and African American adults. Am J Clin Nutr. 2010;91(1):7–15. [PubMed: 19828714]

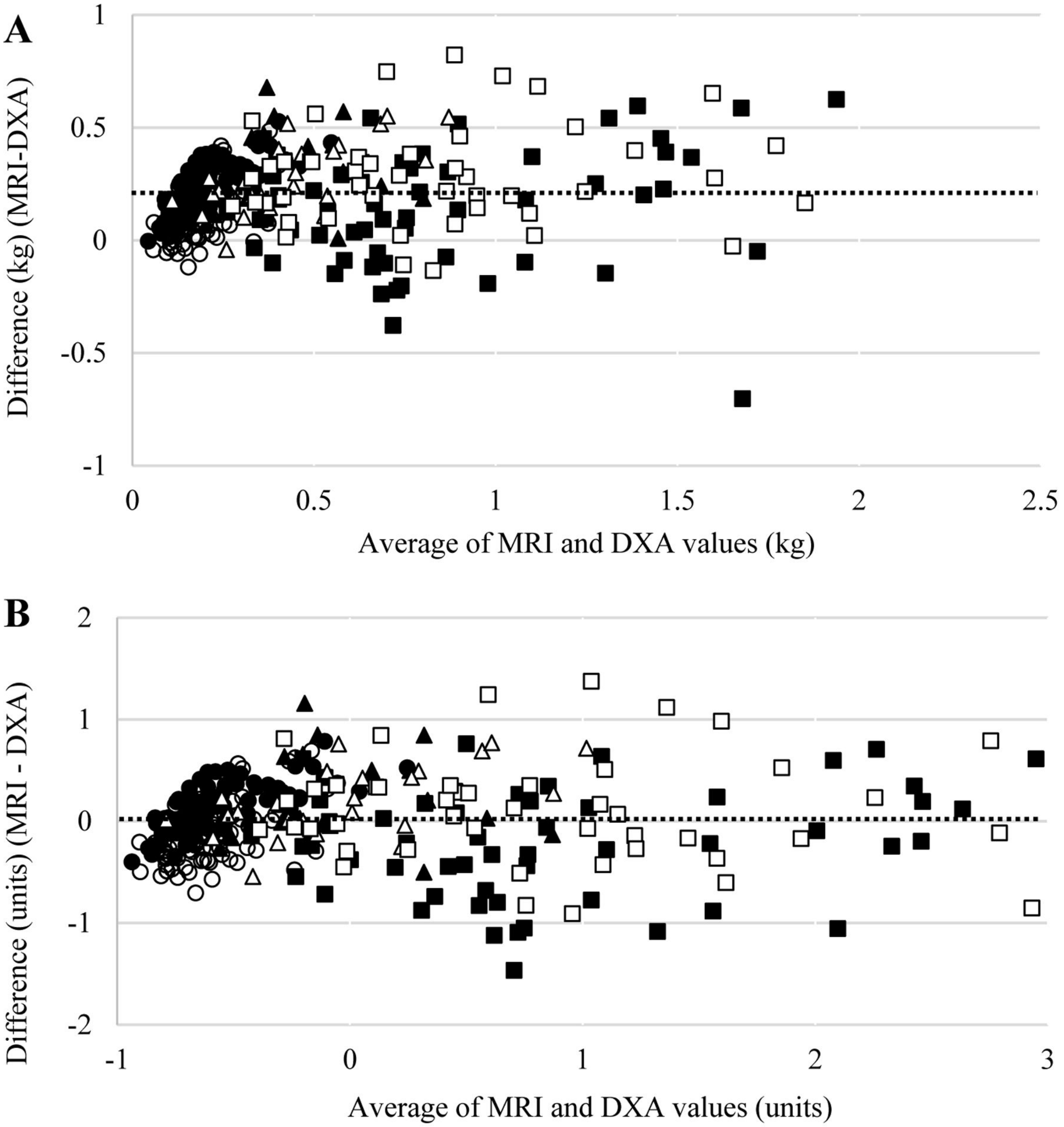

Figure 1.

Bland-Altman plot of Values Panel A: Comparison of Unstandardized MRI and DXA Values Panel B: Comparison of Standardized MRI and DXA Values Dotted line represents mean value of difference (Panel A: 0.20 kg, Panel B: 0.0 units);

Table 1.

Comparison of VAT values using MRI and DXA by Individual Characteristics (n=330)[^]

	n	MRI (kg)	DXA (kg)	MRI – DXA Difference (kg)	*p*-value
Overall	330	0.54±0.43	0.33±0.39	0.20±0.18	<0.001[*]
Sex					
Male	156	0.53±0.48	0.33±0.39	0.19±0.18	<0.001[*]
Female	174	0.54±0.39	0.33±0.39	0.20±0.18	<0.001[*]
Race					
White	193	0.58±0.49	0.34±0.41	0.24±0.17	<0.001[*]
African American	117	0.48±0.35	0.35±0.38	0.12±0.19	<0.001[*]
Other Race	20	0.44±0.19	0.17±0.17	0.27±0.12	<0.001[*]
BMI Category					
Normal Weight	173	0.27±0.13	0.10±0.07	0.17±0.12	<0.001[*]
Overweight	48	0.55±0.22	0.26±0.16	0.28±0.16	<0.001[*]
Obese	109	0.94±0.50	0.73±0.46	0.21±0.25	<0.001[*]

VAT = Visceral Adipose Tissue, MRI = Magnetic Resonance Imaging; DXA= Dual energy X-ray Absorptiometry, BMI = Body mass Index;

[^] Assessed using Wilcoxon rank sum tests,

[*] p<0.05